Lecture 6

- Review

- User defined datatype
  - Structures
  - Unions
  - Bitfields

- Data structure
  - Memory allocation
  - Linked lists
  - Binary trees

Review: pointers

- Pointers: memory address of variables
- '&' (address of) operator.
- Declaring: **int** x=10; **int** *px= &x;
- Dereferencing: *px=20;
- Pointer arithmetic:
  - `sizeof()`
  - incrementing/decrementing
  - absolute value after operation depends on pointer datatype.

Review: string.h

- String copy: `strcpy()`, `strncpy()`
- Comparison: `strcmp()`, `strncmp()`
- Length: `strlen()`
- Concatenation: `strcat()`
- Search: `strchr()`, `strstr()`

Searching and sorting

Searching

- Linear search: $O(n)$
- Binary search: $O(logn)$. The array has to be sorted first.

Sorting

- Insertion sort: $O(n^2)$
- Quick sort: $O(n \log n)$

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Structure

Definition: A structure is a collection of related variables (of possibly different types) grouped together under a single name. This is a an example of **composition**–building complex structures out of simple ones.

Examples:

```
struct point
{
  int x;
  int y;
};
/*Notice the ; a the end */
```

```
struct employee
{
   char fname[100];
   char lname[100];
   int  age;
};
/*members of different
   type */
```

Structure

- **struct** defines a new datatype.
- The name of the structure is optional.
  struct {...} x,y,z;
- The variables declared within a structure are called its *members*
- Variables can be declared like any other built in data-type.
  struct point ptA;
- Initialization is done by specifying values of every member.
  struct point ptA={10,20};
- Assignment operator copies every member of the structure (be careful with pointers).

Structure (cont.)

More examples:

```
struct triangle
{
    struct point ptA;
    struct point ptB;
    struct point ptC;
};
/*members can be structures */
```

```
struct chain_element
{
  int data ;
  struct chain_element *next;
};
/*members can be
  self referential */
```

Structure (cont.)

- Individual members can be accessed using '.' operator.

```
struct point pt={10,20};   int x=pt.x;   int y=pt.y;
```

- If structure is nested, multiple '.' are required

```
struct rectangle
{
    struct point tl ; /*top left */
    struct point br; /*bot right */
};
struct rectangle rect ;
int tlx= rect.tl.x;        /*nested */
int tly= rect.tl.y;
```

Structure pointers

- Structures are copied element wise.
- For large structures it is more efficient to pass pointers.
  void foo(**struct** point *pp); **struct** point pt; foo(&pt)
- Members can be accesses from structure pointers using '->' operator.

```
struct  point  p={10,20};
struct  point  * pp=&p ;
pp->x  =10;    /*changes  p . x*/
int  y= pp->y;    /*same as  y=p.y  */
```

Other ways to access structure members?

```
struct  point  p={10,20};
struct  point  * pp=&p ;
(*pp).x  =  10;  /*changes  p . x*/
int  y=  (*pp).y;    /*same as  y=p.y  */
```

why is the () required?

Arrays of structures

- Declaring arrays of int: **int** x[10];
- Declaring arrays of structure: **struct** point p[10];
- Initializing arrays of int: **int** x [4]={0,20,10,2};
- Initializing arrays of structure:
  struct point p[3]={0,1,10,20,30,12};
  struct point p [3]={{0,1},{10,20},{30,12}};

Size of structures

- The size of a structure is greater than or equal to the sum of the sizes of its members.
- Alignment

```
struct {
char c;
/*padding */
int i;
```

- Why is this an important issue? libraries, precompiled files, SIMD instructions.
- Members can be explicitly aligned using **compiler** extensions.

```
__attribute__((aligned(x))) /*gcc*/
__declspec((aligned(x))) /*MSVC*/
```

Union

A union is a variable that may hold objects of different types/sizes in the same memory location. Example:

```
union  data
{
    int    idata ;
    float     fdata ;
    char * sdata ;
}  d1,d2,d3;
d1. idata=10;
d1. fdata=3.14F;
d1. sdata= "hello world";
```

Unions (cont.)

- The size of the union variable is equal to the size of its largest element.
- **Important:** The compiler does not test if the data is being read in the correct format.

  ```
  union data d; d.idata=10; float f=d.fdata; /* will give junk */
  ```

- A common solution is to maintain a separate variable.

```
enum dtype {INT ,FLOAT,CHAR};
struct variant
{
    union data d;
    enum dtype t ;
};
```

Bit fields

Definition: A bit-field is a set of adjacent bits within a single 'word'. Example:

```
struct    flag {
unsigned   int  is _color :1;
unsigned   int  has_sound : 1 ;
unsigned   int  is _ntsc :1;
};
```

- the number after the colons specifies the width in bits.
- each variables should be declared as **unsigned int**

Bit fields vs. masks

CLR=0x1,SND=0x2,NTSC=0x4;	**struct** flag f;
x|= CLR; x|=SND; x|=NTSC	f.has_sound=1;f.is_color=1;
x&= ~CLR; x&=~SND;	f.has_sound=0;f.is_color=0;
if (x & CLR || x& NTSC)	**if** (f.is_color || f.has_sound)

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Digression: dynamic memory allocation

void *malloc(size_t n)

- `malloc()` allocates blocks of memory
- returns a pointer to **unintialized** block of memory on success
- returns NULL on failure.
- the returned value should be cast to appropriate type using (). **int** * ip=(**int** *)malloc(**sizeof**(**int**)*100)

void *calloc(size_t n,size_t size)

- allocates an array of n elements each of which is 'size' bytes.
- initializes memory to 0

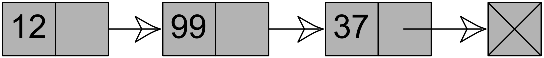
void free(**void***)

- Frees memory allocated my malloc()
- Common error: accessing memory after calling free

Linked list

Definition: A dynamic data structure that consists of a sequence of records where each element contains a **link** to the next record in the sequence.

- Linked lists can be *singly linked*, *doubly linked* or *circular*. For now, we will focus on *singly* linked list.
- Every node has a *payload* and a link to the next node in the list.
- The start (*head*) of the list is maintained in a separate variable.
- End of the list is indicated by NULL (*sentinel*).



Linked list

```
struct node
{
    int data; /* payload */
    struct node* next;
};
struct node* head; /* beginning */
```

Linked list vs. arrays

	linked-list	array
size	dynamic	fixed
indexing	O(n)	O(1)
inserting	O(1)	O(n)
deleting	O(1)	O(n)

Linked list

Creating new element:

```
struct node * nalloc ( int data )
{
    struct node * p=( struct node *) malloc ( sizeof (node )) ;
    if ( p!=NULL)
    {
        p->data=data ;
        p->next=NULL;
    }
    return p;
}
```

Linked list

Adding elements to front:

```
struct node * addfront ( struct node * head , int data )
{
  struct node * p= nalloc (data );
  if ( p==NULL) return head ;
    p->next=head ;
  return p;
```

Linked list

Iterating:

```
for ( p=head ; p!=NULL; p=p ->next )
   /*do something */

for ( p=head ; p->next !=NULL;p=p ->next )
   /*do something */
```